Stampare su carta intestata del CdS

General information		
Academic subject	***Collider Physics***	
Degree course	*Physics*	
Academic Year	*1st*	
European Credit Transfer and Accumulation System (ECTS)		6
Language	*English*	
Academic calendar (starting and ending date)	*2nd semester (March 2022 – June 2022)*	
Attendance	*Yes*	

Professor/ Lecturer	
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Virtual headquarters	*Teams*
Tutoring (time and day)	

Syllabus	
Learning Objectives	*This course covers the principles and the techniques that are currently used to make accurate experiments at colliders to verify the predictions of the Standard Model and beyond. The course aims at providing both a detailed description of the most recent experimental data, and the understanding to place these experimental results in theoretical context. The student will become familiar with the phenomenology of high-energy collisions with reference to classic, current, and future experiments. She/he will acquire the basics on the functioning of accelerators and on multipurpose detectors.* *Through different examples, also with support of dedicated seminars from experts on the field the course aim at providing the tools and understanding about how to design and conduct an experiment: set the physics goal, identify the measurements, define the proper accelerator technology, simulation with event generators, conceptualization of detector [type, shape, size, material, costs…], performance study (detector & physics), detector optimization and aspects related to the construction, commissioning and operation, data selection and analysis and finally publish the publication of the results.*
Course prerequisites	*Institution of nuclear and subnuclear physics, Elements of Particle Detector Physics, Element of Statistical Data analysis*
Contents	*Physics at colliders:* - *The early days of the Standard Model at colliders.* - *Recent experimental data and understanding to place these experimental results in the theoretical context: the open issue in Standard Model and the search for physics beyond Standard Model at colliders.* - *Basic concepts on the particle accelerators: sources and injectors, storage rings, accelerators. Basic properties of the delivered beams at the interaction points in collider mode and fixed target mode. Kinematics, rates, cross-sections, PDFs, luminosity etc..* - *Current and future colliders* *Description of the particle detectors within large experimental apparatus at*

	accelerator facilities. For each of the following application the state of art in the technology will be presented: - *micro-vertex detectors, tracking systems, particle identification, calorimeters, muon detectors, particle flow.* - *trigger systems* - *multi-purpose apparats* *Fundamental parameters and figures of merit of the detectors:* - *efficiency, material budget, acceptance, occupancy, spatial resolution for tracking detectors, momentum resolution for tracking detectors, energy resolution, timing properties, etc* *Software tools and methods for simulation:* - *Monte Carlo simulations and event generators.* *From raw data to physical objects:* - *track reconstruction: global fit methods and Kalman filter approaches* - *vertex reconstruction* - *b-tagging* - *jet reconstruction* - *electron/photons reconstruction and identification* - *tau reconstruction and identification* - *muon reconstruction and identification* *Data analysis:* - *from physical objects to derived quantities (invariant mass, missing energy, event shape variable etc.)* - *Efficiency, background evaluation and suppression techniques. Data driven techniques and Monte carlo based.* - *Statistical Techniques for High Energy* *Critical discussions on how to design and conduct an experiment, present the results (with seminars from experts on different fields):* - *set the physics goal, identify the measurements, define the accelerator, simulation with event generators, conceptualization of detector [type, shape, size, material, costs…], performance study (detector & physics), detector prototyping and optimization, detector fabrication, commissioning and operation, data selection and analysis and how to publish results*
Books and bibliography	- *W.R. Leo, Techniques for nuclear and particle physics experiments Springer-Verlag* - *D. Perkins, Introduction to high energy physics, ed. Cambridge University press* - *Cahn & Goldhaber, The experimental foundations of particle physics, ed. Cambridge University press*
Additional materials	*Teacher' slides and other materials on internet*

Work schedule			
Total	Lectures	Hands on (Laboratory, working groups, seminars, field trips)	Out-of-class study hours/ Self-study

			hours
Hours			
	32	*30*	*88*
ECTS			
	4	*2*	

Teaching strategy	
	Lectures will be delivered in person or in streaming via Teams. A blended learning approach will be adopted by combining traditional face-to-face class lectures with the use of digital technologies. Classroom lessons supported by video projector and with the help of networked PCs and, if needed, in streaming via Teams. Provision of digital content and seminar aimed at deepening the topics covered by the course, followed by a discussion in classroom.
Expected learning outcomes	
Knowledge and understanding on:	*The student will acquire:* • *Knowledge of the theories underlying modern particle collider experiments.* • *Understanding how to apply these theories to calculate experimentally measured observables.* • *Knowledge of the lepton and hadron collider, long baseline neutrino facilities basics: kinematics, PDFs, Monte Carlo methods, experimental techniques.* • *Understanding on how to look for different types of signals.* • *Knowledge of the basics of the accelerator physics.* • *Knowledge of the different particle detectors, the state of art of the technologies and their applications in the context of current and future large experimental apparatus at colliders.* • *Knowledge of the basic tools for global event reconstruction, vertexing, tracking, particle identification, calorimeters, and muon detection, triggering and data acquisition.* • *Knowledge of the software tools relevant for the different analyses.* • *Understanding on how to treat the data, make a statistical analysis, and evaluate the systematic uncertainties in typical measurements at particle collider* • *Understanding how to submit a scientific work for a publication.* • *Critical thinking, creativity, and analytical skills.*
Applying knowledge and understanding on:	*The course provides indispensable tools for gathering the knowledge and understanding to carry out autonomously the research work in particle physics, detector physics and data analysis in the contest of international physics program at colliders. By means of various examples, the course aims to provide the tools for designing and conducting an experiment: definition of the physical objective, identification of the measurements, definition of the accelerator, simulation with event generators, conceptualization of the detector [type, shape, size, material, cost...], study of the performance (detector and physics), prototyping and optimization of the detector, manufacture of the detector, commissioning and operation, selection and analysis of data and publication of results.* *The student will acquire the know-how to apply knowledge in different contexts and will be able to perceive the interdisciplinary value of the theories and experimental methodologies learned.* *The student will acquire knowledge and understanding of experimental methods*

	and techniques to do high-level research in any field, including in an international context.
Soft skills	• *Making informed judgments and choices* *The student will develop the ability to analyze the phenomenology with a critical attitude, having the theoretical and experimental tools to verify the properties and foundations of the proposed theories and models. The student will learn how to analyse a problem and results, and develop critical skills to get autonomously conclusions, highlighting, where possible, the approximations and assumptions and any weaknesses in the reasoning.* • *Communicating knowledge and understanding* The student will acquire skills on how to present scientific concepts and results in a precise, accurate and direct way. He/she will develop an aptitude to share the opinions with colleagues and working in groups to understand problems and to infer the solutions and the research strategies through scientific discussion. • *Capacities to continue learning* *The student will learn how to consult bibliographic material, databases, and scientific literature, in order to continue her/his studies in the field of experimental, theoretical particle physics and any other discipline with an open-minded and interdisciplinary approach.*

Assessment and feedback	
Methods of assessment	*Oral examination will consist of a colloquium typically around topics explained during the course and of a discussion on one article, previously agreed with teacher, in which relevant particle experimental particle physics results are presented.*
Evaluation criteria	• Knowledge and understanding *At the end of the course, it is expected that the student is familiar with basics of collider physics and the theoretical and experimental aspects of Electroweak, QCD and physics beyond Standard Model.* *The student must know the theories underlying modern particle collider experiments. She/he must understand the problematics related to different measurements at colliders, and how to look for different types of signals. She/he should be acquainted with the lepton, hadron collider and long baseline neutrino facilities basics: kinematics, PDFs, Monte Carlo methods, experimental techniques. He/she has the basics of the accelerator physics. The student should know the different particle detectors, the state of art technologies and their applications in the context of current and future large experimental apparatus at colliders. She/he should have acquired the basic tools for global event reconstruction, vertexing, tracking, particle identification, calorimeters, and muon detection, triggering and data acquisition. The student should understand how to use the software tools relevant for which type of analyses.* *She/he should understand how to treatment the data, make a statistical analysis, and evaluate the systematic uncertainties in typical measurements at particle colliders. Finally, the student should know how to present the scientific work.* • Applying knowledge and understanding

	The student should know the theories underlying modern particle collider experiments and understand how to apply these theories to calculate experimentally measured observables. The student should have acquired the competences to carry out autonomously the research work in particle physics, detector physics, computing, and data analysis in the contest of physics program at particle accelerator facilities. She/he should have developed the skills to project and conduct a physics experiment at a particle collider. *The student has the knowledge and understanding of the experimental methods and techniques for doing high-level research in any field also the context of international collaboration.* • Autonomy of judgment *The student should have acquired the ability to identify problems by making qualitative and quantitative observations, analyze them with a critical attitude.* *She/he should be able to identify the relevant measurements to verify properties and the models. She/he has acquainted the tools to conceives the most appropriate experiment apparatus to carry out the measurement, according to a decision-making process which considers the risks assessments related to the design of a large apparatus. She/he can carry out the scientific research in different fields and autonomously getting conclusions through the analysis and interpretation of experimental data.* • Communicating knowledge and understanding *The student must demonstrate the ability to express him/herself using the appropriate terminology, commonly used in high energy and elementary particle physics.* *He acquitted with the tools necessary for the presentation of the scientific data: treatment, estimation, and reduction of the statistical and systematic uncertainties in typical measurements at particle colliders.* *She/he should be able to study a scientific paper, understands the results and present them.* • Communication skills *The student has the skill to communicate scientific concepts in proper lexicon and appropriate English language, to work in a group and to develop strategies for problem solving by comparing with colleagues and teachers.* *He/she can communicate with other coworkers by asking questions and listening to answers, debating in a clear and critically way.* *She/he should be able to analyze a scientific paper, evaluate the experimental techniques and the results and infers future developments, by supporting a scientific discussion using the learned topics.* • Capacities to continue learning *The student should demonstrate to have gained the skills to consult efficiently the bibliographic material, databases and material on internet. The student should be able to study independently, by selecting properly the sources, texts, scientific literature, and web resources, with an open-minded and interdisciplinary approach. In order to expand the knowledge, she/he should be able to select*

	interesting topics, address and solve new problems, and acquire new tools.
Criteria for assessment and attribution of the final mark	*Oral examination consisting of a colloquium typically around topics explained during the course and of a discussion on one article, previously agreed with teacher, in which relevant particle experimental particle physics results are presented. The final mark is given in thirtieths. The examination is considered passed when the mark is greater than or equal to 18.* *The following aspects will be assessed:* - *Acquisition of knowledge and understanding of concepts. Maximum score can be achieved if a very broad, complete, and in-depth knowledge of the contents is demonstrated.* - *Ability to relate the concepts and their implications and ability to apply the contents. Maximum score can be achieved if excellent ability to analyse, synthesize and make interdisciplinary connections is demonstrated.* - *Use of appropriate language and terminology* - *Expository skills and mastery of exposition.*
Additional information	